



United States Marine Corps

Chemical Biological Incident Response Force (CBIRF)

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Blast Injuries

Objectives

- Describe basic blast physics, mechanisms of injury, and pathophysiology of blast injury.
- List four categories of blast injuries
- List factors associated with increased risk of primary blast injury

Blast Injuries

Objectives

- Recognize key diagnostic indicators of serious primary blast injury
- Recognize the most common cause of death following an explosion

Primary Blast Injury (PBI) unique to HYE, injury results from impact of sudden increase in air pressure produced by explosion with body surfaces.





Secondary Blast
 Injury – injury
 resulting from
 <u>fragments</u> propelled
 by an explosion
 impacting with body
 surfaces



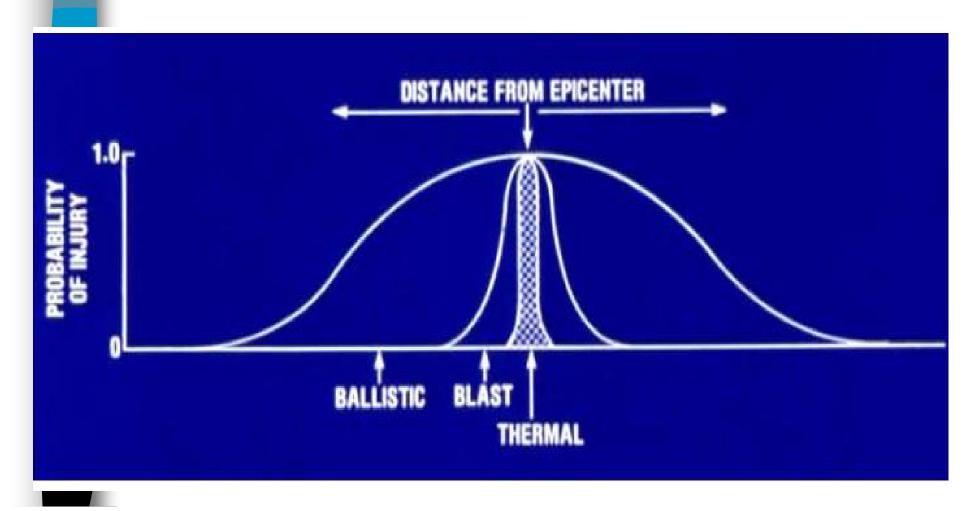
- Tertiary Blast Injury injury resulting from physical displacement of the body by the blast wind (body thrown against objects or impact with ground).
- Crush and burn injuries often present in addition to primary, secondary and tertiary blast injury. If building collapse occurs, crush injury is a major cause of death and injury.

- Quaternary Blast Injury All explosion related injuries, illness or death not due to primary, secondary or tertiary mechanisms.
- Types of injuries: Burns, crush injuries, closed and open brain injuries, Asthma, COPD, or breathing problems from dust, smoke or toxic fumes.

Secondary Blast Injury

- Number one source of injury/death from explosions of all types
 - Fragments: from fragmentation munitions, "spiked" terrorist bomb (Nails, nuts, screws)
 - Fragments: from blast environment
 - Glass fragments are common cause of injury & death related to terrorist blast in urban setting.

If close enough to be seriously injured by blast wave victim is usually killed by fragments



Primary Blast Injury

Primary Blast Injury (PBI): caused directly by the <u>sudden increase in air</u> <u>pressure</u> after an explosion [Blast wave or shock front that travels faster than the speed of sound]

How will this cause trauma to tissue???

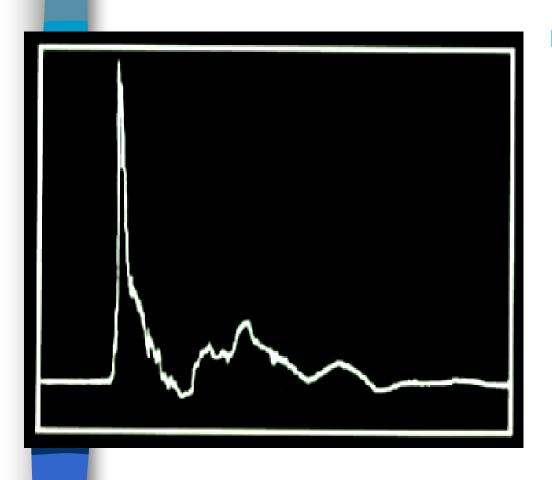
Physics of the Blast Wave - PBI



- Compression of surrounding air or water
- Differential pressures at surfaces

Car crushed by blast wave

Physics and Pathophysiology of the Blast Wave

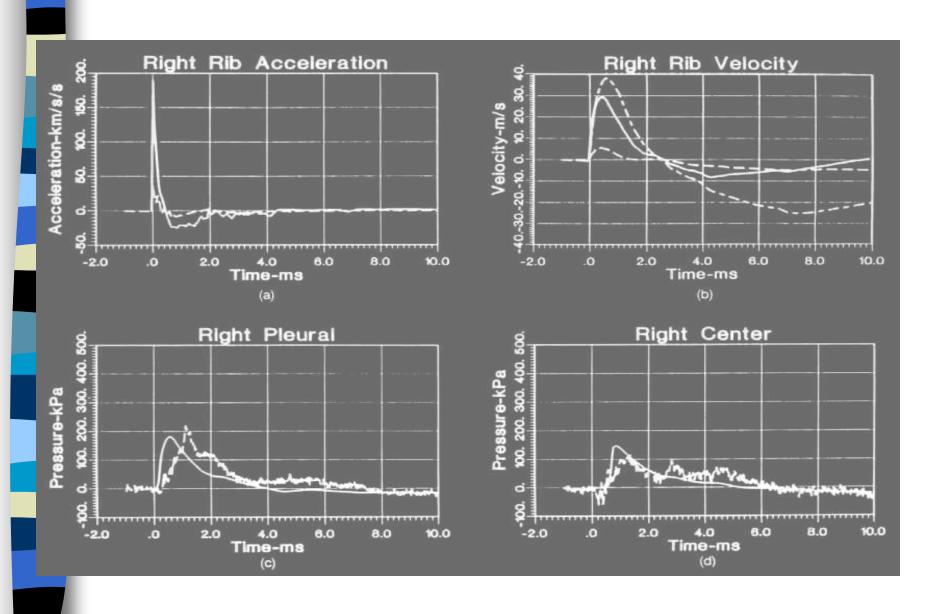


- Differential pressures in tissues:
 - Organ distortion
 - Tensile strength exceeded
 - Tissue Tearing

HUMVEE Destroyed by IED Blast



Rib Acceleration by incident blast wave



Effects of Stress Waves Pulmonary Injury



Bruises on the lungs produced when primary blast wave rapidly accelerates ribs into underlying lung tissue

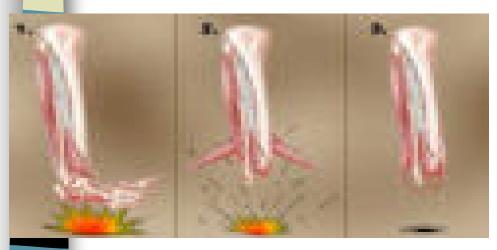
- Blood vessels stretched and torn causing pulmonary contusion
 - Mild interstitial
 hemorrhage with
 minor oxygen
 diffusion problems

Effects of Stress Waves Pulmonary Injury



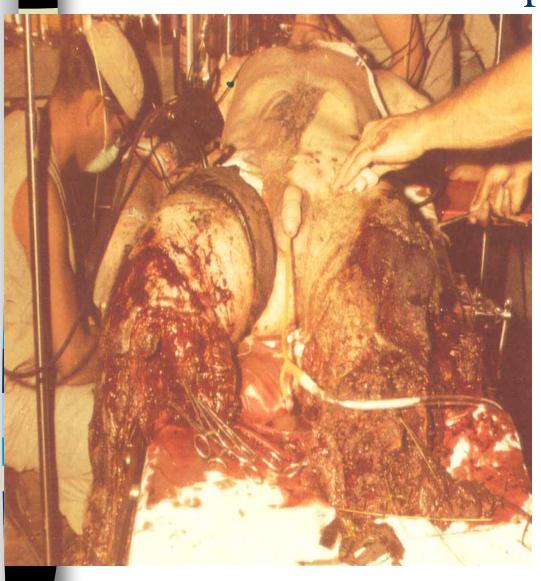
- Blood vessels stretched and torn causing pulmonary contusion (bruising)
 - Severe interstitial and alveolar blood and fluid with <u>major</u> <u>oxygenation and</u> <u>ventilation problems</u>

Effects of Stress Waves Traumatic Amputations



- Blast wave creates stress wave through skin and muscles
- Stress wave shatters solid bone
- Landmines
 - Expanding gasses
 enter and expand
 tissues while ripping
 off distal part.

Effects of Stress Waves Traumatic amputations



Distant explosions

 Blast wind rips off distal part of extremity

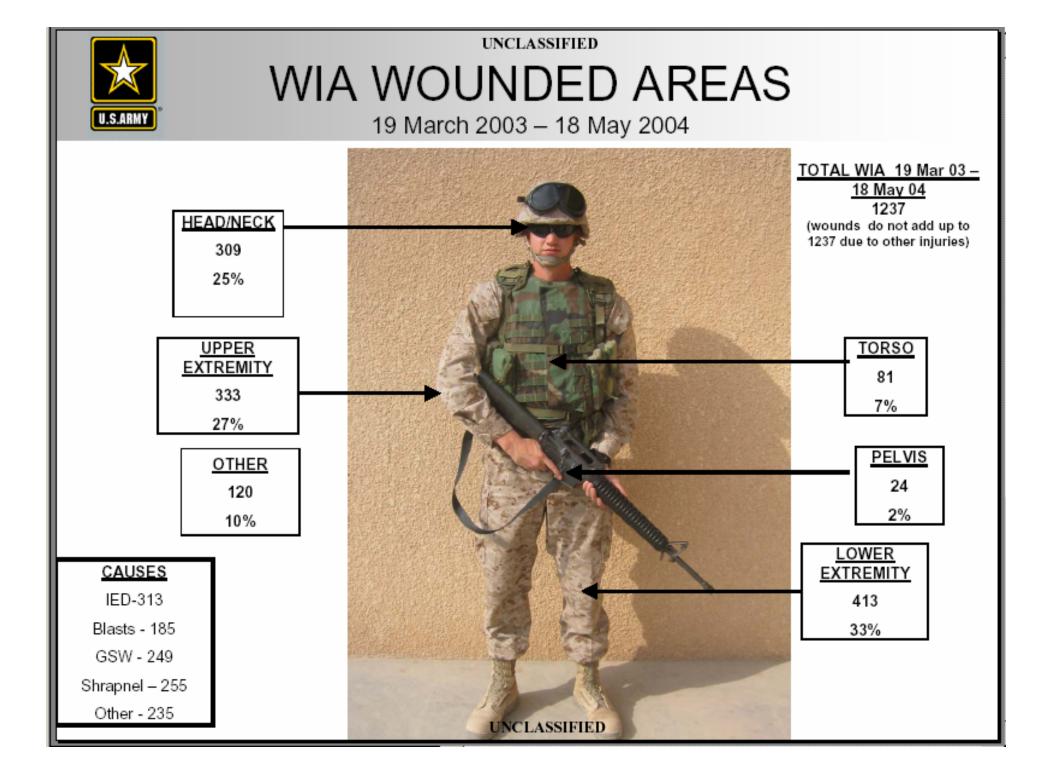
Extremity Amputation IED Blast



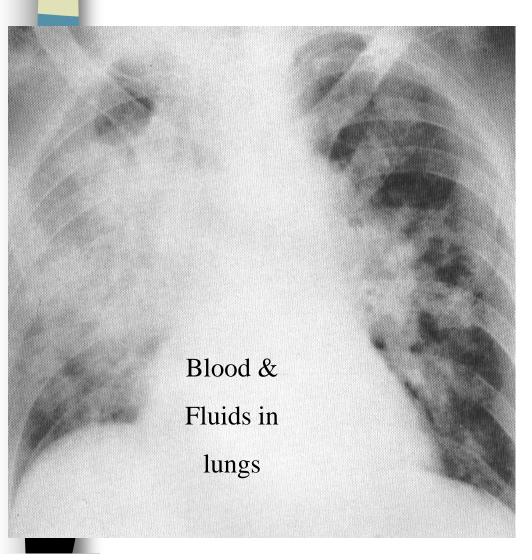
Lower Extremity IED Blast to previous victim



- Organs most sensitive to blast effects are air filled (damage is produced at the interface between air and water)
 - middle ear: ear drum rupture @ 5 psi
 - the respiratory system
 - lungs and bronchi: <u>lung damage at 15 psi</u>
 - upper airways (trachea, pharynx and larynx)
 - nasal passages and sinuses
 - the **bowels**.
- LD₅₀ is around 50 psi.
- (air embolism is 1° cause of <u>sudden death</u> due to blast



Identifying Pulmonary Injury Blast lung



Respiratory difficulty

- With exertion
- At rest
- Asymmetrically or patchy decreased breath sounds or inspiratory crackles
- Decreased S_aO₂ on ambient air or 100% oxygen therapy
- Pulmonary infiltrates on chest radiograph

Chest Injury from RPG Blast

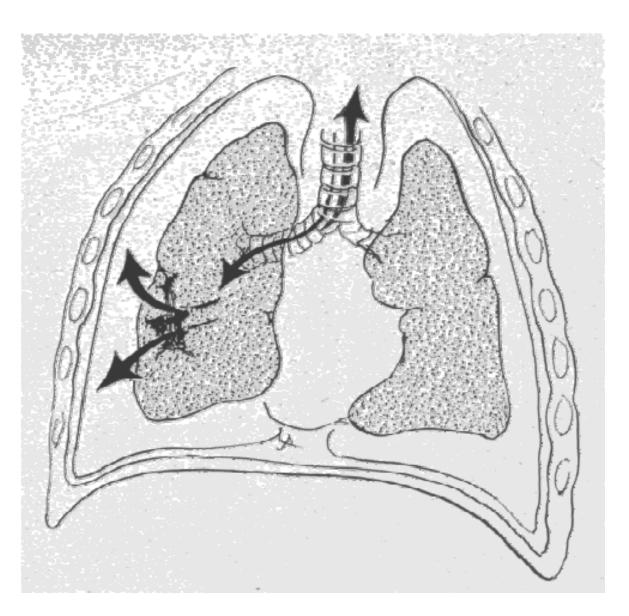


Identifying Pulmonary Injury More Respiratory Injuries

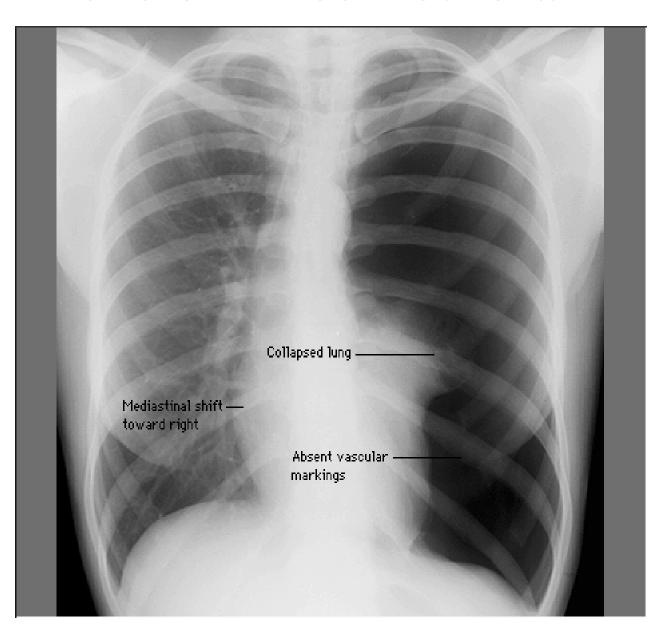
- Alveoli disrupted
 - Pneumothorax
 - TensionPneumothorax

- Asymmetrically decreased breath sounds
- Tracheal deviation to unaffected side
- JVD
- Shock if enough pressure in hemithorax to cause mediastinal shift (tension pneumothorax)

Pneumothorax



Tension Pneumothorax



Identifying Pulmonary Injury

- Alveoli disrupted
 - Pneumothorax
 - Tension pneumothorax
 - Arterial gasembolism (AGE) –

Air bubbles enter the blood stream and travel to brain and/or heart causing stroke and/or heart attack

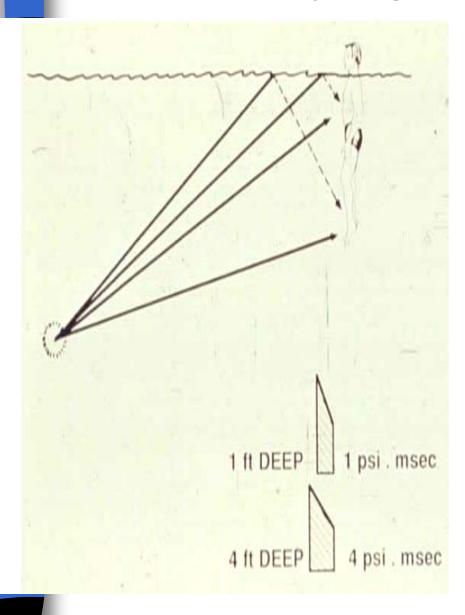
- Cerebral circulation
 - Stroke
 - Seizures
 - Altered mental status
- Coronary circulation
 - Dysrhythmias
 - Ischemia or infarction
 - Cardiogenic shock

Identifying Pulmonary Injury

- Parenchyma torn
 - Pulmonary laceration
 - Hemothorax
 - Bronchopleural fistula

- Pneumothorax
 - [air between lungs and chest wall]
- that is not relieved with large-bore chest tube on oneway valve

Identifying Abdominal Injury



More common in underwater blasts

- Acute/Delayed perforation of the bowel [no obvious external wound – easily missed]
 - Early hemorrhage
 - Delayed sepsis
- Pathology
 - Mesenteric tears
 - Hematomata in bowel wall
 - Intraluminal hemorrhage
 - Delayed perforation up to 8 days after injury

Identifying Abdominal Injury



- Serial abdominal examinations
- Serial hematocrit determinations
- Diagnostic studies
 - Ultrasonography
 - Peritoneal lavage
 - Computed tomography

- Variables Affecting Severity of Primary Blast Injury
 - Severity of injury produced by blast effect of an HE weapon decreases rapidly as the distance of the patient from the blast increases.
 - "Blast Environment" is a very important factor determining the extent of injuries.
 - Nearby structures may either act as a shield or may reflect the blast wave onto a casualty.
 - Orientation of body relative to blast wave end-on orientation minimizes injury

- Tissue susceptibility to primary blast is inversely proportional to Distance³ for any given explosive charge double the distance from the explosion and reduce the injury by a factor of 8
- The most effective way to minimize injury from primary blast injury is to increase the stand-off distance

- Use of standard <u>soft body armor</u> significantly <u>increases primary blast</u> <u>injury</u>
- However, the over all risk of death is higher from secondary blast injury.

Blast Injury - Military Threats

CONVENTIONAL

- Blast from firing of a weapon (Muzzle blast etc.)
- Blast in foxhole
- Blast behind armor
- Underwater Blast
- Terrorist bombings
- Enhanced blast weapons
- Accidental explosions
- Nuclear

Blast Overpressure From Weapons

- Injury from blast is a function of
 - Intensity
 - Pressure and impulse for short duration waves
 - Pressure alone for long-duration waves
 - Number of shock waves
 - Repeated exposure to blast waves <u>significantly</u> increases severity of injury/likelihood of death
 - <u>Larynx</u> is <u>most sensitive</u> non-auditory structure <u>to</u> repeated blast followed by GI and lungs.

Blast In Foxhole/Bunker? Blast Injury?

We found the wounded men...[they] had an uncovered hole under a tree. It must have been their first action because you never have an open hole under a tree in areas that are under enemy shell fire. There were five men in the open hole. A German shell had hit the tree and burst. I checked them over for bleeding and could not find any wounds that required immediate attention. However, they seemed to be in a great deal of pain....Our...doctors checked the wounded men and could not find any bad wounds. They were perplexed as to what was wrong.

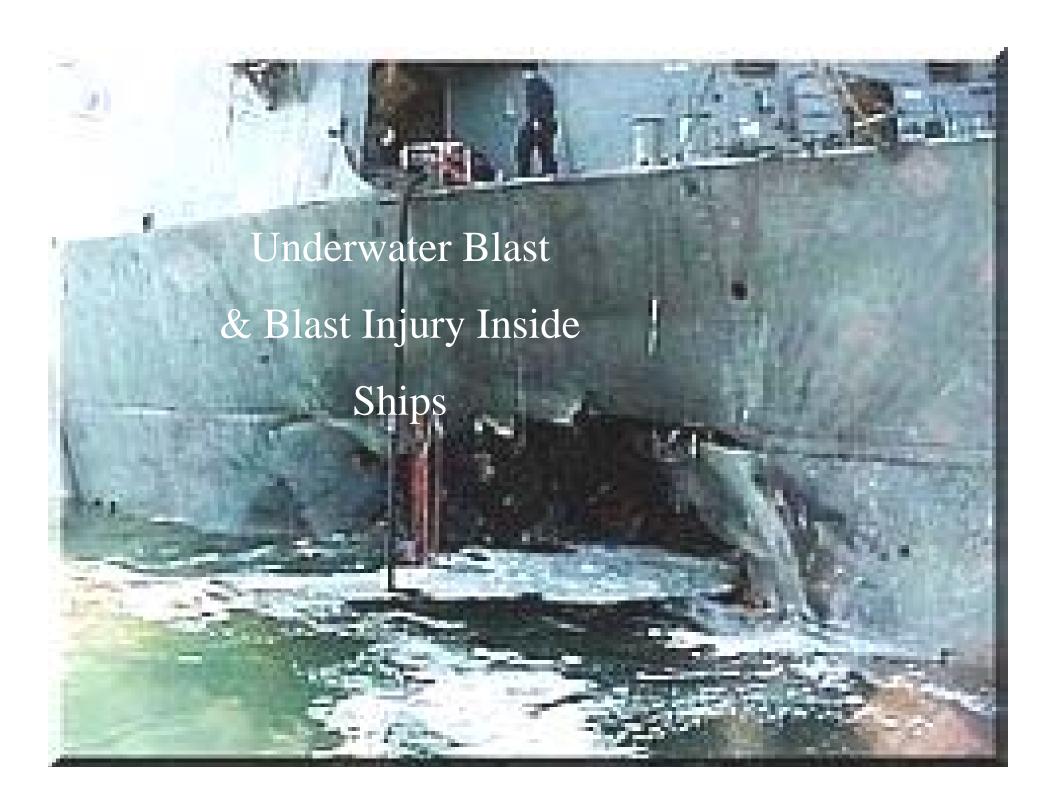
<u>Doctor Danger Forward</u> by Allen Towne, p.112 McFarland & Co. Inc. Publishers, London 2000

? Blast Injury ? (cont.)

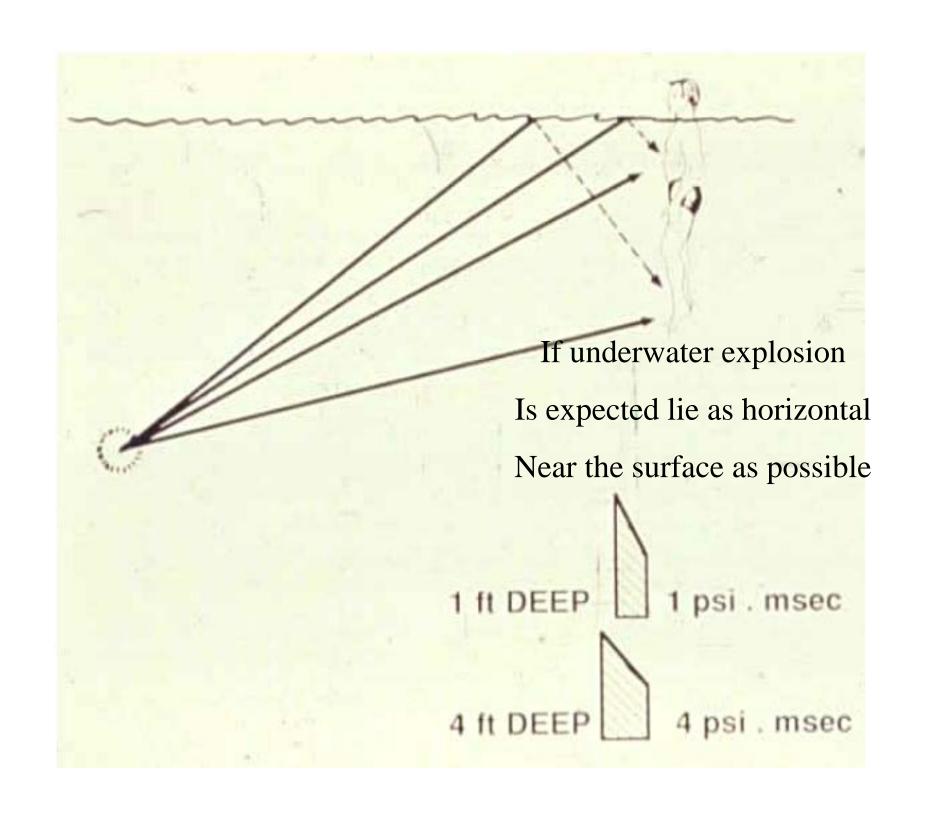
■ The wounded men were very angry and expected us to do something so the doctors decided to give them plasma. We were just starting to given them blood plasma when one by one, all five men died. The doctors speculated that the men had so many steel splinters in them that they were all cut up inside and had bled to death internally. I was shocked by the death of...men who did not seem to have any bad wounds. I was also surprised by the reactions of these wounded men Doctor Danger Forward by Allen Towne, p.112 McFarland & Co. Inc. Publishers, London 2000

Blast in foxholes

- Blast occurring over simple foxholes can readily generate complex blast waves.
- The static overpressure from an explosion directly over a foxhole causes a wave to propagate into the foxhole and reverberate.
- Depending upon the size and shape of the foxhole and the location of soldier in it, the effective overpressure loading can be greater than the incident blast wave itself.



- Explosive forces under water
 - Much more devastating at a greater distance than same forces in the air because the pressure wave travels much faster in water
 - If near an underwater explosion a person who is <u>vertically oriented</u> in the water at/near the surface has a significantly greater amount of blast <u>energy imparted on</u> the <u>abdomen than</u> on the <u>lungs</u>.



- 35 of 125 (28%) of sailors who safely abandoned ship wearing life preservers died after being exposed to a near-by depth charge explosion
- In WWII 24 sailors were rescued after surviving an underwater explosion but within days 11 died, 7 with intestinal perforations.

- 1967 Arab-Israeli War
 - Eliat Destroyer Sunk by torpedo
 - 32 sailors exposed to underwater blast survived to be rescued.
 - 31 suffered primary blast injury (PBI)
 - 27 had blast lung with 5 requiring ventilatory support
 - 24 had abdominal signs and underwent laparotomy – 22 had bowel perforations
 - 4 of the 32 rescued died 3 expired during or shortly after general anesthesia

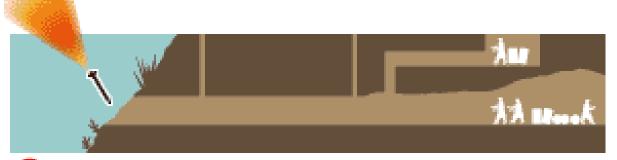
- 13 soldiers swimming for recreation were exposed to a nearby underwater explosion
- All quickly got out of the water
- Within a minute 2 had cardiac arrest
- Within 10 minutes 2 more died
- Within 30 minutes 2 more died.
- The remaining 7 were evacuated by helicopter but ultimately <u>only 3 survived</u>.

- Sir Zachary Cope observed during WWII that —
 - "...if the person were floating on the back so that neither the abdomen nor the chest were directly opposed to the blast, no serious injury was sustained."
- Underwater exposure to the explosion of a 1 lb. charge causes death at 23 ft. This is 3X farther than the lethal range in air

Blast Wave

- Blast inside of a closed space Reflected Blast waves
 - A blast wave that is reflected from a perpendicular barrier (i.e. wall) can create a reflected region with a peak pressure
 10X greater than that of the incident wave.
 - Blast waves inside buildings are repeatedly reflected creating a "complex blast wave"
 - Marked increase in injuries related to primary blast effects when explosion occurs in a closed space

BLU-118B Thermobaric bomb



Precision guided bomb strikes cave entrance



Primary explosion: Fine aerosol mist of highly explosive chemical mixture penetrates the caves



Secondary explosion blasts through tunnels at supersonic speed Pressure wave kills anyone sheltering deeper within the complex Enhanced

Blast

Weapons

BLU-118B

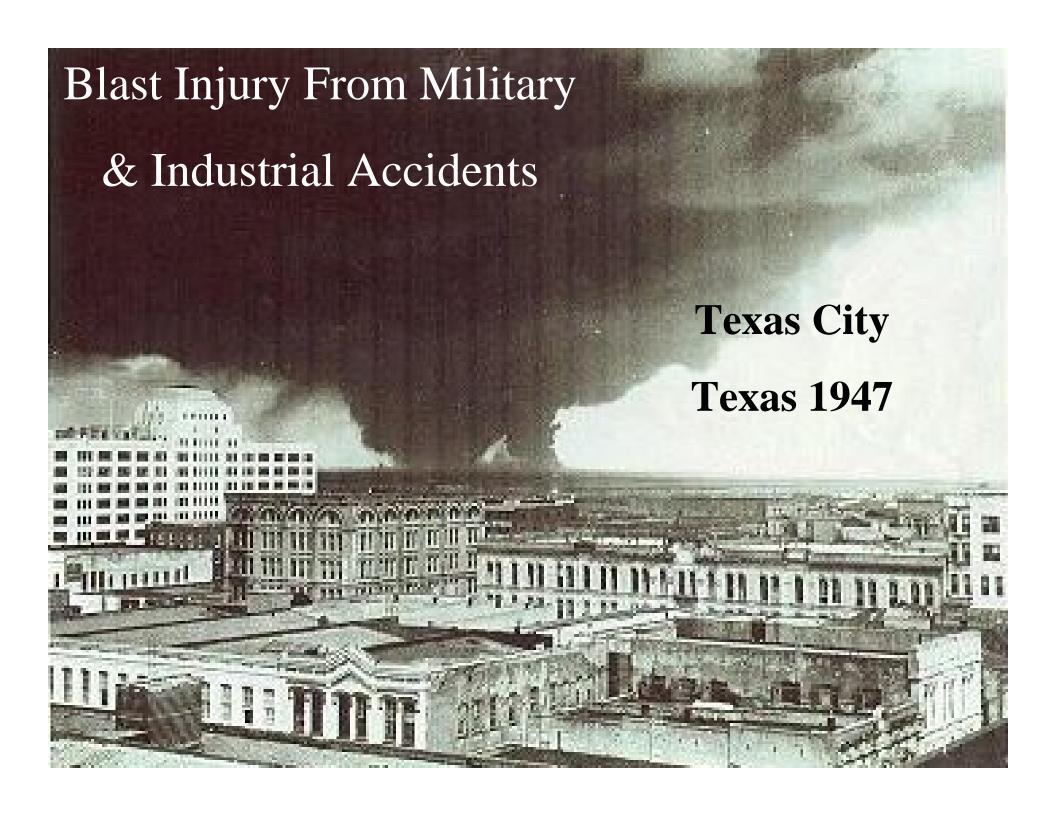
Thermobaric

Bomb



Pre-Explosion

Post-Explosion





Texas City Texas - 16 April 1947 Approx. 8:00 A.M.

longshoremen prepare to load *Grandcamp* with remainder

ammonium nitrate fertilizer 2,300 tons were already onboard

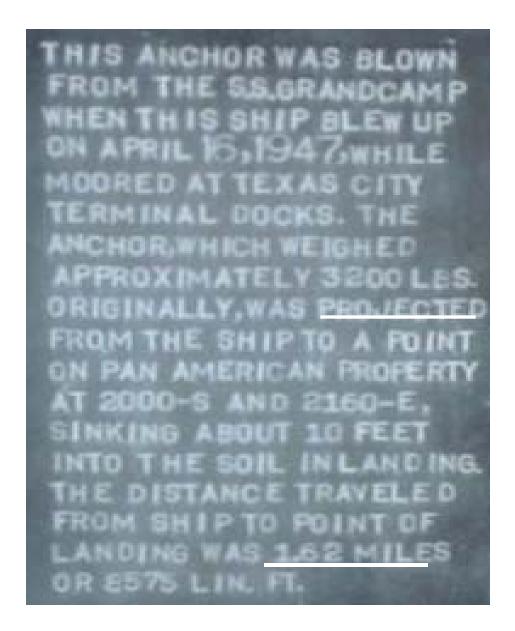
Rest of the cargo consisted of twine, peanuts, drilling

equipment, tobacco, cotton, and a few cases of small

caliber ammunition. A fire was discovered in the hold of the

ship. At 0912 hrs the ship's ammonium nitrate load exploded





Texas City Texas Disaster April 16, 1947

Texas City Texas Disaster

- 405 identified and 63 unidentified dead.
 Another 100 persons classified as "believed missing" no trace of remains ever found
- Estimates of <u>injured</u> (imprecise) roughly 3,500 persons
- Total # of casualties equivalent to 25% of the towns estimated population of 16,000
- Aggregate property loss nearly \$100 M (>\$700 M in today's money)

Medical Management Issues In Primary Blast Injury



Blast Injury

Potential for Occult [not obvious] Injury

- Blast wave may pass through a solid structure
 (hull of a ship or wall of a tank) and produce
 serious injury such as multiple fractures, disruption
 of major blood vessels, or damage to internal
 organs without disruption of the solid structure
 itself.
- These injuries may occur <u>without damage to the skin</u>.

Blast Injury

- Potential for Occult Injury
 - Blast injured patient <u>may have no</u> evidence of <u>external injury</u> despite serious internal injuries.
 - May be overlooked by medical personnel until it is too late.

Blast Injury - Management

- MANDATORY LITTER PATIENT (L) lat. decubitus position w/head lower than feet (AGE position)
 - Don't allow the patient to assist in own rescue or exert him/her self in any way
- Airway control minimize airway pressures as much as possible. Positive pressure ventilation only when necessary
- Frequent vital signs
- Good IV access monitor fluid administration carefully – avoid overhydration/ARDS!

Summary

- Most explosions cause conventional trauma familiar to medical providers (penetrating/blunt injury)
- Primary blast injuries of the lung
 - Leads to pulmonary contusion with possible arterial gas embolism to the brain or heart
 - May rapidly worsen if casualty exerted
 - May affect <u>evacuation decisions</u> (air *vs* ground) air evac only at LOW altitude
- Management of other injuries adjusted
 - Spontaneous breathing or low airway pressures
 - Highest level of oxygen supplementation
 - Just enough fluid or blood to restore perfusion
 - May help to position differently than supine





References: (Presentation largely obtained from "Blast and Ballistic Injuries")

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